



**SET 3**

JULY 2015

# **EXPERT TECHNICAL GUIDE**

---

**FESPA**  
profit for purpose

**INK**

**GUIDE 1: OVERVIEW**

## IT'S ALL ABOUT THE INK

Ink has been around since 2300 BC, so we can be pretty confident that this is a mature and well-developed technology. And then there's the money. Global ink revenues in 2011 were some \$20 billion, most of which came from the offset sector. Offset is the predominant print process and the method for which the greatest range of inks is available. However as digital processes take hold throughout the graphic arts, we will eventually reach a point where the dominance of conventional printing methods, such as offset and screen, starts to be undermined.

The first dedicated printing ink was developed when Gutenberg invented his movable type printing press in around 1452. His initial recipe was oil based and included soot, varnish and egg white. The addition of turpentine and walnut oil to the soot however produced a superior ink that would stick to a printing surface without blurring. Most printers continued to make their own ink until the early 19th century when the first specialty ink company, Lorilleux, was founded in France and the first ink making process was patented.

Four colour wet process inks were introduced in the early 20th century at about the time of the invention of the first litho press and just before rotogravure was invented around 1910. In the 1930s letterpress became popular and the first pigmented flexo inks were developed at about the same time. Throughout history the pace of developments in printing methods has driven ink innovation and continues to accelerate, as new digital printing methods and application demands emerge. Printing innovation is the driver for new ink products which create new opportunities for printers and print buyers in all sectors of the industry.

## WHAT IS INK?

Ink is a chemical recipe. Its manufacturers succeed on the basis of knowledge, experience, research and development, and the strength of patent portfolios. Most are at heart chemical companies specialised in developing and producing inks specifically for different printing methods and applications. There is a huge range of ink products for use in offset lithography, gravure, flexography, letterpress, screen and digital printing, including inkjet and toner devices. Ink producers have a profound knowledge of colour science, rheology and dispersion technologies. Rheology governs how liquid inks flow and dispersion technology ensures that the right chemical agents are present in the ink, for instance, to prevent pigment particles clumping together. Large particles of pigment can mean that the ink does not present in a smooth layer, adversely affecting colour brilliance.

Ink chemistry is a necessarily complex business because an ink recipe's composition affects its appearance when dry, drying requirements, performance on press and in use. The chemistry delivers varying levels of durability, deinkability, lightfastness and fitness for purpose, whether the ink is for food packaging, synthetic and natural textiles such as polyester, silk, linen or cotton, flooring, furniture, décor, wallpaper and so on. Ink formulation, how inks work with different printing technologies and interact with different media, requires constant research and development and patenting to protect intellectual property. Inks are also subject to specific labeling requirements relating to health and safety, storage, use and restrictions on their disposal.

The mixing of colorants and other ingredients to produce the required ink coloration and performance is as much art as science. For printing companies an awareness of how different ink recipes work in different situations is vital to any investment decision.

## WHAT'S IN IT?

All inks comprise a carrier, either liquid or paste, plus colorants. The carrier, also referred to as the binder, is the vehicle which delivers colorants to a substrate. It is normally made up of resins dissolved in mineral oil plus other additives such as fluorescents, solubilisers, surfactants and particulate matter, like metal particles, to give an ink its particular characteristics and flow properties. The binder can also be water.

The ink's viscosity meaning its stickiness and consistency, determines its fluidity and so suitability for different print processes. For instance, flexography requires low viscosity inks to achieve good quality. In gravure printing very low viscosity is achieved with powerful solvents, however this can affect optical ink density. In screen printing where there is a huge array of print methods and applications, the ink's viscosity must be tuned to the size of the screen mesh and the desired ink layer thickness.

The binder may also include thinning agents such as water or solvents, which can sometimes make up the bulk of the ink but then can in part be recycled. For instance toluene, a solvent used in gravure printing to dissolve the binding substances around pigment particles, can be mostly recycled. Some manufacturers have replaced petroleum based ingredients with vegetable based or renewable ones, to reduce solvent use.

Pigments are insoluble solid particles held in a suspension, or molecules that are gathered into a mass. Pigments make up between 5% and 30% of an ink's volume, with the volume varying according to the colour tone of the ink. A pigment particle can be made up of millions of molecules only a small proportion of which actually end up on the substrate surface to respond to light. Pigmented inks are widely used because they are more

colourfast than dye based inks, but they can be more expensive and inconsistent in colour rendering and they have a smaller colour gamut than their dye based equivalents.

Dyes are dissolved molecular organic compounds. The molecules interact with other ingredients in the ink, so dyes are potentially more able to benefit from additives to the carrier fluid such as Optical Brightening Agents (OBAs) and other colour enhancing additives. However these inks are not waterproof and have a relatively low UV resistance, so prints with dye-based inks need to be laminated for outdoor use. They can tend to be cheaper, stronger and of denser colour than pigmented inks, but they can also sink into a substrate or slither about on a coated surface, which can make them difficult to control.



Understanding how to manage ink usage can help you to get the most out of print technology innovations.

Additives influence an ink's flow behaviour, drying and abrasion resistance, which are especially important considerations for applications such as packaging and signage printing and for printing matte coated papers. An ink's viscosity affects its performance especially on press and in the final print appearance. Solvents and hot air blowers are used for rapid drying of highly viscous inks for instance in some screen printing applications, especially for thick ink layers. Ink manufacturers have also developed special surface coatings for substrates to improve ink performance and control the behaviour of the ink.

Solvent and pigment ingredients are also added for shine and enhanced colour. Solvents are Volatile Organic Compounds (VOCs) that contain heavy metals and nonrenewable oils, but which have low boiling points and so evaporate quickly. They are selected for ink recipes according to various criteria such as the VOC's boiling point, flash point (the temperature at which the solvent produces enough vapour to ignite), odour, safety, toxicity and explosion limit. Commonly used VOCs in printing inks are ethanol, ethyl acetate and water to which alcohol has been added. However solvents are extremely unhealthy so the trend for several years has been towards the use of vegetable rather than petroleum oils in printing inks.

Water is used as a carrier solvent for some types of gravure packaging printing. It is also used for inkjet inks such as latex ink used in wide format digital printing, and for some offset press technologies.

## **SUBSTRATES**

The physical and chemical properties of a substrate determine ink requirements. In all sectors of conventional printing this relationship is well understood and there are ample options for print buyers. However media compatibility of inkjet inks is less mature. Most inks for digital printing are specific to the media and the printing method. Some solvent, eco-solvent, UV-curable and latex inks all work with the same print media and the same is true for some applications printed with UV-curable, latex and dye-sub inks. But the lines are vague so it is best to always check the media compatibility of inks and to test wherever possible. There is a notable shift from PVC to polypropylene materials in the sign and display market, so an ink's ability to print on both should be checked if this is required.

## **INK CHARACTERISTICS**

There are four categories of ink used in printing: powder, paste, aqueous and liquid inks. Inks are characterised by features such as their transparency, important in a subtractive colour process, their printability, flow properties and drying, gloss, behaviour on press, light and abrasion resistance. How well the ink works with substrates, its adhesion and stability are also important. For instance antimigration ink stops migration of polyester dyes in food packaging. Some highly creative applications in the sign and display business can benefit from a cracking ink that produces crackled effects. Elasticity is a major requirement for vehicle wrapping, where inks must be stretchable without compromising colour appearance or breaking away from the substrate. Inks may even have to have thermoforming properties, for instance for use in three dimensional printing.

## INK PERFORMANCE

For printers and their customers the primary consideration is how the ink can be expected to perform. Inks are formulated for specific sectors of the printing industry, so newspaper inks are designed to print on newsprint, UV inks for packaging and label printing, screen inks for screen printing and so on. Screen printing works with a huge range of substrates and applications, so there are many diverse requirements for these inks. They must meet the needs of commercial screen printing for sign and display, silk screen printing, industrial screen printing for cups, toys and promotional materials, and special processes such as textiles, or printed circuit boards. Uneven and difficult surfaces such as leather and porcelain which are printed using pad printing technology, also make their own demands on inks.



A colour bar is used to check colour density and to maintain consistency over the course of the printrun.

Perhaps the most important behavioural expectation for productive and cost effective print, is that the transfer process doesn't interfere with the rest of the printing process and that it meets the application requirements. The ink transfer mechanism and how

ink is dried or fixed to the substrate determine the ink's structure and recipe. The ink splitting process affects the ink's design, so how the process creates the ink film must be taken into account when determining performance objectives. Inks used in direct ink film transfer such as with hot embossing or thermotransfer will have different requirements to other processes. How the ink is pressed through a screen in screen printing, or gets jetted onto the substrate in inkjet printing influence ink performance and so its composition and drying requirements.

Ink can be dried through various means, depending on its chemical composition. Most common is by physical absorption or evaporation, but inks also dry chemically by way of oxidation or radiation curing, or by solidification as is the case with hot melt inks.

Another important consideration for an ink is its adhesive properties. Adhesion requirements depend on the demands of the application. Ink mechanically adheres by sinking into pores or fibres in the substrate surface, which generally requires pressure. Ink may sink into the surface by capillary action, which is how inkjet printing works, or ink is bonded by the chemical and physical effects of the ink and substrate. These processes can be combined.

The ink's flow properties determine its suitability for different print processes. Inks can range from being very thin and watery to almost dry and powdery as is the case with electrophotography. Their recipes vary according to the required appearance in print, from simple black text through to metallics and pearlescent inks. If an ink is used for food packaging it must have low odour and

low migration properties. Other factors shaping ink design are toxicity and emissions controls.

## **INK CONSIDERATIONS**

From an investment perspective there are numerous factors to consider that are specific to the requirements of your business. In no particular order they include the ink's productivity, cost, colour gamut, drying performance and speed of cure, VOC emissions and energy consumption. Other considerations are the need for primers and coatings for a given substrate, gloss and chromatic performance, resistance to edge chipping and colour concentration. If you have multiple presses using different print processes, you may additionally need to ensure colour matching compatibility with other inks and ink recipes across devices and across processes. You may also have legislative constraints, possibly requiring adaptations to your factory for compliance, and perhaps requirements for risk labelling in textiles and soft signage.

## **ISO STANDARDS**

One way to improve quality control is to request that supplied inks conform to the ISO 2846 series of standards. This series specifies requirements for the colour and transparency of printing ink sets for four-colour printing for sheetfed/heatset web, coldset/newspaper, gravure, screen and flexo inks, but does not cover digital inks. The standard is a useful guide for conventional print processes, and is necessary for compliance to the ISO 12647 series for print process quality control. But even if an ink complies

with ISO 2846 you should test inks thoroughly. Test for the ink's colour and transparency characteristics under specific printing conditions, and be sure to run tests on the full range of media you expect to print with the print methods you will use.

Graphics professionals have two major questions to resolve when it comes to ink: performance and cost. The cost of ink is highly subjective. Inks are designed to work with multiple processes to maximise income streams for their developers and manufacturers. Ink prices are very much subject to supply and demand and volumes purchased. Inks sold in the greatest volumes such as for commercial offset or conventional screen printing cost less per kilo than small amounts of exotic inkjet inks that only work with a particular printhead. Investments for your plant should take into account the cost of inks and the provider's business model, for instance click charges or contracts based on annual consumption.

## **CATEGORIES OF INKS**

Solvent inks are any ink that is not water based. These inks are durable and vibrant, and suitable for outdoor use. They contain varying amounts of solvents and so are classed accordingly. Some solvent inks can contain a lot of solvents and some less. The type and character of the solvent components influences ink performance. Solvent inks are UV light, water and scratch resistant and when printed they partially dissolve the substrate and bond with it. The intensity of this etching process depends on the amount and type of solvents in the ink. Materials printed with solvent inks are durable but potentially difficult to deink, so these prints are not always environmentally friendly. These prints dry rapidly in air but in some printing systems they are dried with heat

which is applied at different stages of production, pre-, during and post printing, depending on the printing system. Solvent inks are hazardous, so ventilation equipment is required to extract fugitive fumes. Solvents are widely used in gravure printing for publication and packaging printing, and wide format digital printing for applications such as vehicle wrapping, signage, and indeed any application that requires speed, colour quality and quick drying.

Eco-solvent inks are a bit less dangerous and have similar properties to solvent inks but are slower drying. They are durable with excellent light, water and scratch resistance and they are suitable for indoor and outdoor use. They contain lower amounts of VOCs than solvent inks, so they are only somewhat hazardous to health and can be used in an office environment, although the prints have a strong odour.

UV inks contain liquid monomers used to adjust their processing viscosity, and oligomers which work with monomers to form the binder. When the monomers and polymers are exposed to UV light they react and form three dimensional crosslinked polymers. Photo-initiators in the ink are synergists which decompose during UV exposure and trigger polymerisation in a chain reaction, to create a cross-linked structure. The pigments and other additives in UV-curing ink for digital printing are not dissimilar from those used in conventional printing inks.

UV inks cure under UV light and have a completely different structure compared to conventional inks. They are commonly used in conventional and inkjet printing processes to print nonabsorbent materials such as plastics and metals, but increasingly they are used in labelling and sign and display applications, conventional and digital, printing on a growing range of substrates.

UV curing is achieved using mercury arc lamps or more recently Light Emitting Diodes (LEDs) and these inks have some solid advantages compared to solvent based inks. They are almost solvent free, dry almost immediately and can be finished without gassing off. There is no dried ink in the press which makes for cleaner running. UV-curing inks have high mechanical stability and chemical resistance, but they can be expensive as can the curing equipment. Care must be taken to protect operators from exposure to UV light. There can be risks of ink fogging caused by ink misting, a function of print speed, temperature, ink recipe and how the ink is conveyed to the substrate.

UV-curable inks print on most substrates and the inks are cured using UV light. This can be harmful so these inks should be handled using suitable protection. Like solvent inks they have high UV, water and scratch resistance and are suitable for indoor and outdoor use. They are flexible and dry immediately and are used in some screen and offset printing, and extensively in wide format digital printing. Solvent UV inks are a blend of solvents and UV-curing ink, so the amount of solvent is reduced. In other respects they are very similar to solvent inks.

LED arrays for UV-curable ink are designed to emit UV light over very specific wavelength ranges, so the relationship between inks and LED energy must be carefully tuned. This curing technology is an alternative to mercury arc lamps, requiring less than half the energy of conventional lamps. LEDs generate less heat and can last over ten times as long and radiate no infra-red heat, so the printing device can print onto a wider range of substrates including very delicate ones because there is minimal substrate heating. LED output power is also predictable and consistent throughout a diode's life. However they are still slower to cure the inks and

the depth of cure is not as great as with mercury arc lamps. UV-curable inks for LED curing respond to specific wavelengths and cure at much lower power levels and temperatures. However they must respond to the specific spectral outputs of the LEDs and this puts additional demands on the ink formulation.

Latex inks are water based and are claimed to have equivalent performance to solvent inks. These inks are an aqueous polymer dispersion with the ink dried virtually immediately using heat, which limits the substrates they can be used with. Latex inks are used for all sorts of print including flexible applications, such as vehicle wrapping. They pose no health risk and are durable.

Dye-sublimation inks are water based inks, with water evaporated using heat to sublimate ink into the substrate surface. These inks are used in textile printing for lightfast and washable print and mainly used to print flags, soft signage, interior décor and fashion. They are durable and suitable for outdoor applications with a high colour brightness. The inks are nonhazardous, but print media can shrink or distort during printing so they are only suitable for a limited range of media.

Overprint varnishes are inks without colorants. They are used to provide a protective and enhancing layer over the printed image and can be applied inline, wet on wet or off-line, wet on dry. As with ink, there is a bewildering array of coating options and their recipes are determined according to varnish performance requirements and the technology used to transfer the varnish to the print.

## EMERGING DEVELOPMENTS

Ink technology is constantly changing in line with innovation in printing methods. However legislation is an important driver, with regulations such as the European Union's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation which is gradually eliminating harmful substances from the list of ingredients ink makers can use.

There is considerable activity in the area of digital inkjet printing as manufacturers strive to optimise the relationship between printheads inks and substrates to improve performance and quality, and reduce environment impact. Some aqueous inks contain reactive molecules for greater adhesion, durability, resistance and performance on press to provide an alternative to UV curing inks. Low temperature flexible inks for instance save energy and are starting to come onto the market. Water is being used more widely to produce dispersion inks that are non-toxic, low migration and odour free.

Ink is only a small part of the business of producing print media, but its role is crucial. Business owners and operators looking to invest in new kit should always test an ink's behaviour on preferred substrates in order to check the performance of different ink and substrate combinations. Rest assured that whatever printing technology you use and whatever the application, there will be an ink for you.

[WWW.FESPA.COM](http://WWW.FESPA.COM)

 **FESPA**  
profit for purpose